§78. Transport Coefficients of InSb in a Strong Magnetic Field

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One of the authors, S. Y., proposed[1,2] the direct electric energy conversion of the heat from plasma by the Nernst effect in a fusion reactor, where a strong magnetic field is used to confine a high temperature fusion plasma. He called[1,2] the element which induces the electric field in the presence of temperature gradient and magnetic field, as Nernst element. In his paper,[1,2] he also estimated the figure of merit of the Nernst element in a semiconductor model. In his result,[1,2] the Nernst element has high performance in low temperature region, that is, 300 - 500 K.

Before his works, the Nernst element was studied in the 1960's.[3] In those days, induction of the magnetic field had a lot of loss of energy. This is the reason why the Nernst element cannot be used. Nowadays an improvement on superconducting magnet gives us higher efficiency of the induction of the strong magnetic field. We started a measuring system of transport coefficients in the strong magnetic field to estimate efficiency of the Nernst element on a few years ago.[4]

As the first candidate of the Nernst element, we choose InSb, which is expected to have the high figure of merit according to the single-band model.[5] The experimental results show that the Nernst coefficient is smaller than the theoretical values. On the other hand, the conductivity, the Hall coefficient and the thermoelectric power has the values expected by the theory. Transport phenomena in a magnetic field and a temperature gradient are written by two phenomenological equations[6] as follows:

$$E = \frac{J}{\sigma} + \alpha\, \nabla T + R_H\, B \times J + N\, B \times \nabla T, \qquad (1)$$

$$q = \alpha T\, J - \kappa\, \nabla T + N\, T\, B \times J + L\, B \times \nabla T \qquad (2)$$

where E is electrical field, J current density, B magnetic field, T temperature, σ electrical conductivity, α thermoelectric power, R_H Hall coefficient, N Nernst coefficient, κ thermal conductivity and L Righi-Leduc coefficient.

We first propose indium antimonide, InSb as a candidate of the Nernst element. The sample of measurement of the thermoelectric power and the Nernst element is called the "bridged shape" (Fig. 1). In order to make temperature gradient in the sample, we used thermofoil heater for a heating copper block side, the water temperature of which is controlled by a low temperature incubator, for a cooling one. Using the heating and cooling units, the temperature difference across the sample was within 10-100K.

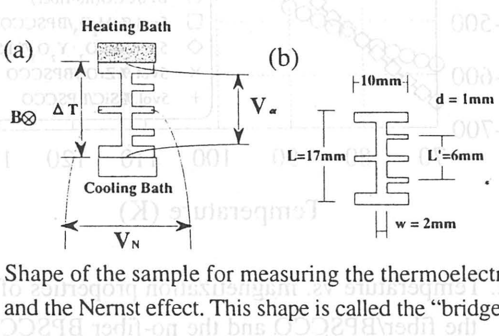

Fig. 1. Shape of the sample for measuring the thermoelectric power and the Nernst effect. This shape is called the "bridged shape".

In Fig. 2(a), we plot the results as the crosses and the theoretical values as the filled circles. The theoretical values are explained in the later. The difference between the experimental results and the theoretical ones is the order of 10. For the strong magnetic field, the results are shown in Fig. 2(b).

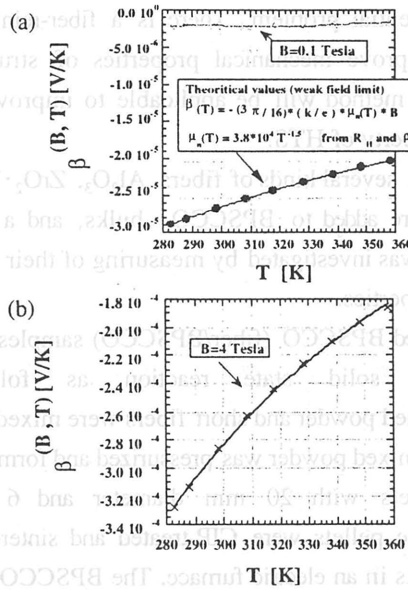

Fig. 2. Plot of Nernst effects, $\beta = N \times B$ in the case of B = 0.1 Tesla (a) and 4 Tesla (b). The crosses indicate the experimental results. The filled circles in Fig. (a) were calculated by the single band model with the mobilities which were given from the Hall coefficients and resistivities. In Fig. (b), the solid curve is given by the least square method.

References

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